

Dusky Sap Beetles (Coleoptera: Nitidulidae) and Other Kernel Damaging Insects in Bt and Non-Bt Sweet Corn in Illinois

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ABSTRACT Bt and non-Bt sweet corn hybrids (Rogers 'Empire' Bt and non-Bt, respectively) were compared for distribution of kernel damaging insect pests in central Illinois in 1998 and 1999. The occurrence and damage by caterpillars [primarily *Helicoverpa zea* (Boddie)] were reduced by at least 80% in each year for the Bt compared with the non-Bt hybrid. However, the incidence of sap beetle adults (primarily *Carpophilus lugubris* Murray) was higher, and larvae, lower for the Bt versus non-Bt in 1999. The incidence of ears with more than five kernels damaged by sap beetles was higher for the Bt compared with non-Bt hybrid in 1998 (13.8 versus 5.5%), but nearly equivalent in 1999 (15.3 versus 15.1%, respectively). Distribution of predators on plants (primarily Coccinellidae) and harvested ears (primarily *Orius* spp.) were not significantly different on Bt versus non-Bt hybrids. Ears with husks flush with the ear tip or with ear tips exposed had significantly higher sap beetle damage for both hybrids, and the Bt hybrids had significantly higher incidence of exposed ear tips in both years. Sap beetle numbers determined by scouting were often proportional to numbers of beetles captured in baited traps, increasing and decreasing at about the same time. However, values determined with traps were typically less variable than when scouted, and time of sampling was typically four times more rapid for each trap than for each 10 plant scout sample when measured in 1999.

KEY WORDS *Helicoverpa zea*, *Carpophilus lugubris*, *Ostrinia nubilalis*, insect predators, insect monitoring, *Bacillus thuringiensis* corn

FIELD CROPS THAT express a *Bacillus thuringiensis* (Bt) crystal protein such as Cry Ia(b) can often control target lepidopterans with little or no effect on beneficial insects, provided expression levels are high enough and properly distributed in the tissues. Growing Bt dent (field) corn can be economically advantageous in areas where target insects, such as the European corn borer, *Ostrinia nubilalis* (Hübner), frequently occur with populations of at least one borer per stalk (Gould 1998). Control of corn earworms, *Helicoverpa zea* (Boddie), in dent corn ears has been more variable, ranging from highly effective (Pilcher and Rice 1997), to very effective (Gould 1998), or of limited effectiveness (Dowd et al. 1998a). Because sweet corn is picked at milk stage, it is likely that even if *H. zea* is not controlled, its development may be slowed enough so that only insignificant damage will occur.

Sap beetles, especially the dusky sap beetle, *Carpophilus lugubris* Murray, can also be major pests of sweet corn in different regions of the United States (Connell 1956a, Sandford and Luckmann 1963, Tamaki et al. 1982). These insects are a particular problem because larvae may be found hidden in kernels throughout the ear (not just the ear tip) (Connell 1956a, Harrison 1960). In some cases, entire truckloads of sweet corn have been rejected by canneries because of sap beetle infestation (Knowlton and Houck

1948). Thus, multiple insecticide treatments for sap beetles in Bt sweet corn may still be necessary (Dively 1996). Scouting these beetles involves searching leaf axils or silks for adults, eggs, or larvae (Dively 1996). However, effective traps (Dowd et al. 1992, Williams et al. 1993, James et al. 1995, 1996), pheromones (review, Bartelt 1997), and formulated coattractants (Bartelt et al. 1992, Dowd et al. 1995, Vega et al. 1995, James et al. 1998) have been reported and could possibly be used as a time saving alternative to scouting.

The current report describes efficacy of a representative Bt hybrid compared with a corresponding non-Bt hybrid sweet corn in reducing incidence of sap beetles and kernel damaging caterpillars in central Illinois over two growing seasons, as well as effects on predatory insects. The incidences of sap beetles determined by scouting and trapping, relative efficacy, and the relationship of population levels to frequency and severity of ear invasion by these insects is also described.

Materials and Methods

Bt Corn. Rogers 'Empire' Bt and non-Bt hybrids (Novartis Seeds, Boise, ID) were planted in eight row strips ≈80 m long at a research site provided by the Central Illinois Irrigated Growers Association near Havana, IL. Cultural practices common to the area

were used and included center pivot irrigation. There were eight alternating strips of each hybrid in 1998 (plus one additional strip of the Bt hybrid) and four alternating strips of each hybrid in 1999.

Ear Evaluation. Five ears with brown, dry silks were picked at each sample position (when available) 21 d after most of the plants had begun silking. Because of nonuniform plant growth, five ears were not collected from all sample positions. Individual ears were evaluated for insect species present, and numbers of kernels damaged by a particular insect species. The degree of husk coverage of the ear tips was also recorded by measuring the distance the ear tip was exposed beyond the husk.

Plant Scouting. Plant scouting for sap beetles began when <5% of the plants were silking, and continued semiweekly for a total of five scouting events. Species were determined based on previously identified specimens (Dowd and Nelsen 1994). Dates of scouting were 28 and 30 June and 3, 7, and 10 July in 1998, and 2, 6, 9, 12, and 15 July in 1999. Plants in the two center rows of each strip were scouted by examining the leaf axil above the main ear, the ear itself, the main ear leaf axil area (between ear and stalk and ear and leaf), and the axil below the main ear for sap beetle adults (Dowd et al. 1998b). Up to 10 plants with silking ears were sampled at 10-m intervals from one edge except where traps were positioned (see below). In 1999, incidence of aphids and lady beetles or other insect predators were also recorded during sample 4, whereas the time required for plant scouting and trap evaluation at each respective sample position was determined during sample 5. The timing commenced once the sample position was reached and concluded once scouting was finished or traps were replaced on hangers.

Sap Beetle Traps. Sap beetle traps were based on a design described previously (Dowd et al. 1992). The design was simplified for commercial manufacturing (Fig. 1a) by using a 3.2-cm-diameter polyvinylchloride (PVC) pipe tee as the entire trap body. Each end of the horizontal portion of the tee had a yellow funnel, with a 1.9-cm-diameter opening (Fig. 1A). A 5 cm long, 2.5-cm-diameter piece of PVC pipe was placed in the leg of the tee (Fig. 1A). A 16-cm-diameter clear polyethylene lid was placed under the horizontal tee so that the tee leg protruded through a hole cut in the lid (Fig. 1A). Two different types of collection jars were attached under the lid. In 1998, a 2.66-liter "Klear-Stor" jar (Anchor Hocking Plastics, Eagan, MN) was used. In 1999, traps manufactured by Bridgeway (Macomb, IL) based on the same design, were used, but these had a clear polystyrene jar of ≈ 11.5 -cm-diameter (850 ml volume) (Fig. 1A). No fins were added to orient the traps because of the limited wind within the corn rows.

Traps were baited with *C. lugubris* pheromone (Bartelt 1997) and fermenting apple juice absorbed into polyacrylamide granules (Dowd et al. 1995, James et al. 1998). The fermenting apple juice was made by adding 100 mg of yeast (Red Star champagne yeast, Universal Foods, Milwaukee, WI) to 100 ml of natural

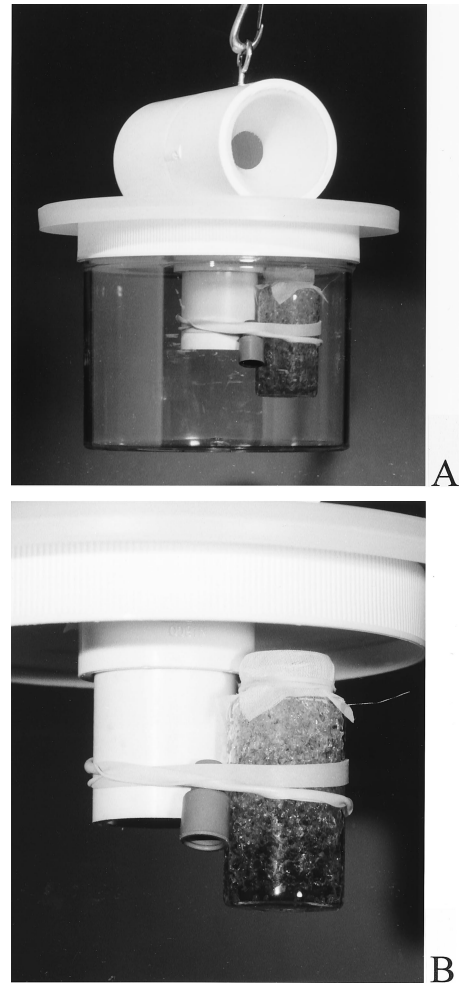


Fig. 1. Trap used for sap beetle captures. (A) Overall trap. (B) Closeup of bait area.

(not reconstituted, no preservatives added) apple juice. Polyacrylamide granules (1.5 g) (Terra-Sorb Hydrogel, A. M. Leonard, Piqua, OH) were added to a 20-ml glass vial, and the vial was filled to the neck with the apple juice/yeast mixture. Granules swelled so that no free liquid remained. The vial was covered with a cotton organdy square (30 threads per centimeter) held in place with a rubber band. The vial and pheromone impregnated septa were attached to the tee leg (Fig. 1B). Traps were hung at corn ear level from a bent electrical conduit that was pushed into the soil so that the trap openings faced up and down the rows. Traps were placed in the field when scouting was started. In 1998, traps were placed between the center two rows of each strip ≈ 20 m from one row edge (one trap per row, total of 17 traps). In 1999, because of the smaller size of the available field, traps were placed 20 m from both row edges (two traps per row, total of 16 traps). Traps were examined once a week (at the same time scouting was done) for 4 wk to determine numbers and species of sap beetles captured.

Table 1. Incidence of insects and damage on harvested milk stage Bt and non-Bt hybrid sweet corn ears

Parameter	% ear incidence			
	1998		1999	
	Bt-	Bt+	Bt-	Bt+
Caterpillars ^a	81.0a	11.1b	22.4a	3.5b
Caterpillar damaged kernels ^b	80.5a	10.2b	18.8a	3.5b
>5 Caterpillar damaged kernels	70.7a	2.7b	17.6a	2.3b
No. of kernels/ear	20.6 ± 0.8a	6.8 ± 3.7b	27.3 ± 2.4a	16.0 ± 1.0a
Sap beetle ^c adults	29.5a	26.7a	2.4a	12.8b
Sap beetle larvae	15.5a	14.7a	30.5a	19.8a
Sap beetle damaged kernels	31.5a	47.6b	60.0a	68.6a
>5 Sap beetle damaged kernels	5.5a	13.8b	15.3a	15.1a
No. of kernels/ear	3.1 ± 0.5a	4.5 ± 0.7a	3.8 ± 0.6a	3.2 ± 0.3b
Ear tips flush or exposed	18.0a	26.7b	78.8a	89.5b
Sap beetle adults	62.8a	63.6a	3.0a	14.3b
Sap beetle larvae	33.0a	35.0a	38.8a	22.2b
Sap beetle damaged kernels	63.9a	86.7b	76.1a	76.6a
>5 Sap beetle damaged kernels	30.6a	51.7b	19.4a	16.9a
Total ears sampled	152	156	85	86

For each year, values in rows followed by different letters are significantly different at $P < 0.05$ by chi-square analysis (incidences) or analysis of variance (numbers of kernels damaged). Five ears taken at positions 15, 45, 60 (in 1999), 75, and 115 in each row whenever ears with dried, brown silks were available (presumably at milk stage).

^a Nearly all caterpillars were corn earworms.

^b Most caterpillar damaged ears had 20 or more kernels damaged.

^c Nearly all sap beetle adults (and presumably larvae) were dusky sap beetles (*C. lugubris*).

Statistical Analysis. SAS programs were used for statistical analysis (SAS Institute 1985). Because of nonuniform insect distribution in the field within row blocks, chi-square analysis was used to determine significant differences in incidence as has been done previously under these conditions (Dowd et al. 1998b). Analysis of variance (ANOVA) was used to determine significant differences in numbers of damaged kernels per ear and correlation analysis was used to determine significant associations between trap or scouting samples and harvested ear samples, or between different types of insect species. For the trap timing counts, regression analysis was used to separate trap handling time and time needed to count specific beetles. The model for this analysis was as follows: total time required = number of beetles × counting time per beetle + trap handling time.

Results

Sap Beetles. The incidence of adults and larvae of *C. lugubris* found on milk stage ears was not significantly different between the Bt and non-Bt hybrids in 1998 (adults, 26.7 and 29.5%; larvae, 14.7 and 15.5%, respectively) (Table 1). In 1999, there were significantly more *C. lugubris* adults on the Bt than non-Bt ears (12.8% and 2.4%, respectively, $P = 0.01$, $\chi^2 = 6.630$), but the percentage of ears with larvae showed the opposite trend (19.8 and 30.5%, respectively, not significantly different at $P < 0.05$). The incidence of ears with more than five kernels damaged by sap beetles was significantly higher for the Bt compared with non-Bt hybrid in 1998 (13.8 and 5.5%, respectively, $P = 0.004$, $\chi^2 = 8.147$). In 1999, the incidence of ears with more than five kernels damaged by sap beetles was approximately the same for the Bt versus non-Bt ears (15.1 and 15.3%, respectively). When damaged ker-

nels were present (in a few cases sap beetles only damaged silks or unfilled kernels), the number of damaged kernels per ear ranged from 3.1 to 4.5 for both hybrids and years.

Significantly more Bt ears had tips exposed compared with non-Bt ears in both years ($P = 0.033$, $\chi^2 = 4.548$ for 1998; $P = 0.05$, $\chi^2 = 3.689$ for 1999) (Table 1). Ears with husks flush with the ear tip or with ear tips exposed had significantly higher incidence of sap beetle damage for both hybrids in both years (Bt $P = 0.000$, $\chi^2 = 50.182$, non-Bt $P = 0.000$, $\chi^2 = 21.344$ for 1998; Bt $P = 0.000$, $\chi^2 = 82.847$, non-Bt $P = 0.000$, $\chi^2 = 61.506$ for 1999). When only ears with exposed tips were considered, the percentage of sap beetle damaged ears was relatively similar in 1998 (86.7 and 63.9% for Bt and non-Bt, respectively) compared with corresponding hybrids in 1999 (76.6 and 76.1% for Bt and non-Bt, respectively). However, the percentage of ears with exposed tips that had more than five kernels damaged by sap beetles was approximately two- to threefold greater in 1998 than 1999.

Semiweekly scouting of corn plants indicated *C. lugubris* adults were typically present in about equal percentages on Bt and non-Bt hybrids from onset of silking through milk stage harvest in both 1998 and 1999 (Table 2). Few other sap beetle species were noted on plants or ears during either year and were rarely found separate from *C. lugubris*, although *Glischrochilus quadrisignatus* Say and *Carpophilus antiquus* Melsheimer were seen sometimes in both years. In both years, the numbers of beetles seen on plants decreased for the last sample or two (Figs. 2 and 3). No significant correlation R^2 values above 0.25 were noted in either year for scouted beetle incidence and harvested ear sample incidence of sap beetles or sap beetle damage at corresponding sample positions.

Table 2. Relative numbers of sap beetles encountered by scouting and trapping

Date	Hybrid type	Sap beetle occurrence			
		Scouting		Trapping	
		% plant incidence		numbers	
		Dusky sap beetle	Total sap beetle	Dusky sap beetle	Total sap beetle
1998					
26 June	Bt+	4.6 ± 4.6a	4.6 ± 4.6a	—	—
	Bt−	0.0 ± 0.0b	0.0 ± 0.0b	—	—
30 June	Bt+	12.0 ± 3.0a	13.8 ± 3.4a	44.4 ± 6.2a	49.7 ± 7.1a
	Bt−	12.6 ± 2.8a	16.0 ± 2.8a	23.4 ± 3.5b	24.6 ± 3.9b
3 July	Bt+	22.3 ± 3.0a	27.4 ± 2.9a	68.2 ± 3.3a	75.6 ± 3.4a
	Bt−	29.7 ± 3.1a	35.9 ± 2.4a	48.4 ± 6.0b	59.7 ± 7.7a
7 July	Bt+	47.8 ± 4.0a	52.4 ± 4.1a	52.8 ± 7.7a	75.1 ± 13.4a
	Bt−	43.1 ± 5.0a	47.2 ± 5.2a	66.4 ± 8.4a	92.0 ± 11.0a
10 July	Bt+	30.8 ± 3.5a	36.4 ± 3.9a	12.7 ± 2.6a	15.1 ± 3.8a
	Bt−	25.6 ± 3.8a	29.4 ± 4.4a	16.5 ± 4.1a	19.2 ± 4.4a
1999					
2 July	Bt+	0.0 ± 0.0a	0.0 ± 0.0a	—	—
	Bt−	0.0 ± 0.0a	0.0 ± 0.0a	—	—
6 July	Bt+	15.6 ± 8.4a	15.6 ± 8.4a	4.5 ± 0.7a	17.8 ± 5.5a
	Bt−	15.8 ± 7.4a	15.8 ± 8.4a	4.2 ± 1.6a	28.8 ± 11.9a
9 July	Bt+	13.0 ± 5.0a	13.0 ± 5.0a	5.5 ± 1.0a	9.9 ± 1.2a
	Bt−	10.0 ± 2.2a	10.0 ± 2.2a	4.1 ± 1.4a	12.5 ± 5.1a
12 July	Bt+	5.2 ± 2.1a	5.2 ± 2.1a	5.1 ± 1.3a	7.5 ± 1.7a
	Bt−	7.2 ± 1.8a	7.2 ± 1.8a	4.8 ± 0.9a	9.4 ± 2.3a
15 July	Bt+	6.3 ± 1.6a	6.3 ± 1.6a	0.8 ± 0.2a	5.1 ± 1.3a
	Bt−	4.0 ± 1.8a	4.0 ± 1.8a	1.9 ± 1.9a	5.0 ± 2.2a

Values in columns of like sample dates followed by different letters are statistically different at $P < 0.05$ by ANOVA. For 1998, maximum total number of possible plant sample spots was 68 and total number of traps was 17. For 1999, maximum total number of possible plant sample spots was 40 and total number of traps was 16.

Trapped *C. lugubris* numbers were similar for Bt and non-Bt rows in both 1998 and 1999 (Table 2). Trapped sap beetle species were primarily *C. lugubris* in 1998, with *G. quadrisignatus* making up most of the rest of the sap beetles captured in 1998. Trapped sap beetle species were primarily *Stelidota geminata* (Say) in 1999, with *C. lugubris* making up most of the rest of the sap beetles captured in 1999. Other species also were captured occasionally and included *C. antiquus*, *Carpophilus brachypterus* Say, *Carpophilus hemipterus* L., and *Conotelus* sp. Numbers of *C. lugubris* determined by scouting were often proportional to the numbers of beetles captured in traps on the same date, with decreases in numbers noted for the last sample in both years, (similar to the trend seen for the plant scouting)

(Figs. 2 and 3). Based on coefficients of variation (CV), *C. lugubris* trap numbers tended to vary less than scout sample numbers, even though the total number of traps was less than half the number of scout samples in both years. For the second through fifth samples, the CVs were <0.5 for 6/8 trap samples and 0/8 scout samples in 1998, and the CVs were <1.0 for 6/8 trap samples and 1/8 scout samples in 1999. Time of sampling was approximately four times more rapid for the traps (33.2 ± 2.2 s) compared with a 10 ear scout sample (126.7 ± 3.3 s) in 1999. The number of beetles present in the traps was significantly correlated ($R^2 = 0.4153$, $P = 0.007$) with the time required to examine the trap. Based on the regression equation derived from the data, handling time alone for the

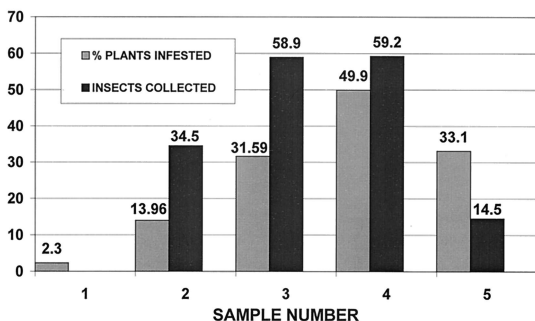


Fig. 2. Dusky sap beetle incidence on Bt and non-Bt corn in central Illinois in 1998.

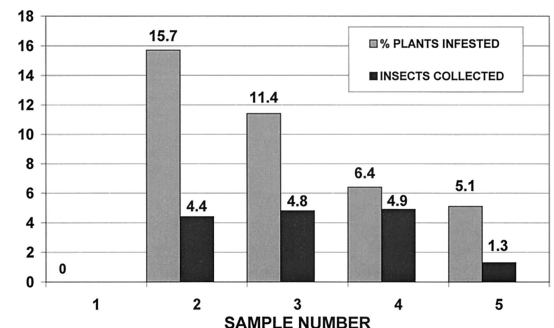


Fig. 3. Dusky sap beetle incidence on Bt and non-Bt corn in central Illinois in 1999.

traps was 27.7 ± 2.1 (SE) seconds (the y intercept), with 1.1 ± 0.3 (SE) seconds to count each captured sap beetle; the residual mean-square error was 38.09.

Caterpillars. Milk stage ears of both hybrids did not have any *Ostrinia nubilalis* (Hübner) in 1998, and only a few on the non-Bt hybrid corn in 1999. The incidence of *Helicoverpa zea* (Boddie) and other caterpillars [rarely *O. nubilalis* or *Spodoptera frugiperda* (J. E. Smith)] was significantly reduced from 81.0 to 11.1% ($P = 0.000$, $\chi^2 = 209.894$) in 1998 for the non-Bt and Bt hybrid, respectively, and the percentages of ears with more than five kernels damaged by caterpillars per ear was significantly reduced from 70.7 to 2.7% ($P = 0.000$, $\chi^2 = 215.340$) for the non-Bt and Bt hybrid corn, respectively (Table 1). In 1999, both caterpillar incidence and incidence of ears with more than five kernels damaged by caterpillars were significantly lower for the Bt than non-Bt hybrid (3.5 and 22.4%, $P = 0.000$, $\chi^2 = 13.571$; and 2.3 and 17.6%, $P = 0.001$, $\chi^2 = 11.208$, respectively). When kernel damage occurred (in some cases only silk damage or damage of unfilled kernels was present), caterpillars damaged a mean of 20.6 ± 0.8 and 27.3 ± 2.4 kernels per ear in the non-Bt hybrid in 1998 and 1999, respectively. When compared with caterpillar damage of non-Bt hybrids, the same type of kernel damage per ear was significantly less for the Bt versus non-Bt hybrid in 1998 (6.8 ± 3.7 , $P = 0.000$; $df = 1, 108$; $F = 18.321$) but not 1999 (16.0 ± 1.0).

Predators. Because of extremely low levels of predators in 1998, values are not reported, and no significant differences in incidence occurred between the Bt and non-Bt hybrids. In 1999, the incidence of aphids (Bt+ = 26.3%, Bt- = 37.5%), but not predatory insects (primarily lady beetle adults and larvae, and occasionally lacewing and syrphid larvae) (Bt+ = 20.5%, Bt- = 22.5%) was significantly lower in the Bt compared with non-Bt plants scouted ($P = 0.018$, $\chi^2 = 5.596$ for aphids). Predator presence was significantly positively correlated with aphid presence (R^2 of 0.8009, $P = 0.0001$, $F = 68.392$; and $R^2 = 0.3412$, $P = 0.0068$, $F = 9.32$) for Bt and non-Bt hybrids, respectively). Predator incidence (primarily *Orius* spp., but also including spiders, lady beetle adults and larvae, and carabid beetle larvae) was not significantly different between the hybrids in harvested ears (31.8 and 32.6%, for non-Bt and Bt hybrids, respectively) in 1999.

Discussion

Control of noncaterpillar pests such as sap beetles by the Bt corn is expected to be low because of the lack of efficacy of the protein against Coleoptera, but may occur indirectly because caterpillar damage, which attracts sap beetles, (Connell 1956a, Sanford and Luckmann 1963, Tamaki et al. 1982) is reduced. However, past studies and the current study indicate this potential indirect control often does not occur. Sap beetle incidence is about the same in dent (field) corn at milk stage for Bt and non-Bt hybrids tested, but sap beetle damage may appear greater in the Bt hybrids because sap beetle damage is often intermingled with

caterpillar damage when caterpillars are present (which does not occur in the Bt hybrids (unpublished data). The same trend for apparent enhanced sap beetle damage in the Bt corn was noted in one year of the current study, but not the other. Other reports from the northeast also indicate little effect on sap beetle damage/presence for Bt versus non-Bt sweet corn (Dively et al. 1998, Whalen and Spellman 1998). Although sap beetles are also present on Bt sweet corn in the southeast, damage is minor (Lynch et al. 1999b).

It appears the exposure of the ear tips, as reported previously (Connell 1956a, Daugherty and Brett 1966), is a major determinant of incidence of sap beetle damage compared with other factors, including population level. The same relationship was noted in the current study. Even though sap beetles were present in higher numbers in 1998 than 1999 as indicated by both trapping and scouting, damage incidence was higher in 1999, when tip exposure was much greater than in 1998. However, the severity of damage per ear was greater in 1998 than 1999 when only ears with exposed tips were considered. Ear tips can be exposed when dry weather is followed by wet under the appropriate timing because the cob will grow for a longer period than the husk (Barber 1944). Weather conditions mimicked this scenario more closely in 1999 than 1998 in the current study, when there was more tip exposure. Regardless of the tip exposure, sap beetles can be as important pests in the Bt hybrids as in the corresponding non-Bt hybrids, and become the major ear damaging insect pest in the Bt hybrids with the reduction in caterpillar damage. With tip exposure being relatively unpredictable, it may be necessary to plan treatments (economic thresholds) on a worse case scenario assuming all ear tips may be exposed. The variety used in the current study, like other Jubilee derived varieties, typically has marginal to exposed tips, depending on environmental conditions (R. Teyker, Del Monte Foods, Rochelle, IL, personal communication).

Because sap beetles may still be important pests in the Bt sweet corn, applications of insecticides may still be required if the population exceeds the economic threshold. Insecticides have been important part of treatment for sap beetles for some time (Darsie 1953; Connell 1956a, 1956b; Whitlaw et al. 1959; Harrison 1974; Tamaki et al. 1982) and are still part of extension recommendations (e.g., Gray and Steffey 1993, Dively 1996, Cranshaw 1998). Monitoring sap beetle populations can prevent unnecessary application of insecticides, and facilitate better timing of insecticide applications. In both years of the current study, sap beetles were seen on plants very early in ear development, often at silk onset, which has been reported previously (Connell 1956a, Sanford and Luckmann 1963), although major ear invasion does not occur until after about 12 d (Sanford and Luckmann 1963). Past extension recommendations have involved scouting for sap beetles (Dively 1996). However, traps for *H. zea* and *O. nubilalis*, are commercially available and can be used as an alternative to scouting (Dively 1996). Effective pheromones (Bartelt 1997), coattractants

(Dowd and Bartelt 1991, Lin and Phelan 1991) and their release devices (Bartelt et al. 1992, Dowd et al. 1995, Vega et al. 1995, James et al. 1998), and traps (Dowd et al. 1992, Williams et al. 1993, James et al. 1996) have been developed for sap beetles such as *C. lugubris*, but are not yet commercially available. The current study indicates traps may be a useful alternative to scouting for sap beetles, although initial calibration for different hybrid types may be needed. The current study also reiterated the importance of husk coverage in addition to sap beetle population levels in determining incidence of sap beetle damage.

Bt dent (field) corn hybrids that express the Bt crystal protein at high levels throughout the plant can typically provide nearly complete control of *O. nubilalis* (Ostlie et al. 1997). These hybrids may also produce good control for the southwestern corn borer, *Diatra grandiosella* Dyar, when an effective gene construct is used (Ostlie et al. 1997). Efficacy of the Bt dent (field) hybrids against *H. zea* appears more variable for the same Bt events. Reported efficacy has ranged from nearly complete control (Rice and Pilcher 1998) to 90% or less (Gould 1998) to not much of an effect on incidence (Dowd et al. 1997, 1998a, 1999). In sweet corn, the Bt gene appears to slow development of *H. zea* sufficiently so that little damage to the ear is noted at milk stage (Dively et al. 1998; Lynch et al. 1999a, 1999b). This trend holds for county regions where *H. zea* control by Bt field corn hybrids is less effective (Dowd et al. 1998a, 1999), as indicated by data from the same region for sweet corn reported in the current study.

Past research on Bt dent (field) corn has indicated that predators are typically not adversely affected (Pilcher et al. 1997), but in some cases predators may be less common in Bt compared with non-Bt hybrid pairs (Dowd et al. 1998a, 2000). However, variation in predator incidence between non-Bt dent (field) hybrids at the same site was often greater than Bt and non-Bt hybrid pair variation (Dowd et al. 1998a, 2000). The current study also indicated no effect on predator distribution on milk stage sweet corn ears (primarily *Orius* spp.), or on scouted plants (primarily lady beetle larvae) that was not prey density related.

Thus, Bt sweet corn may provide sufficient level of control of *H. zea* and *O. nubilalis* in the Midwest that insecticide treatment will not be necessary or can be greatly reduced for these insects, as has been reported in the northeast (Dively et al. 1998) and southeast (Lynch et al. 1999a, 1999b). Although laboratory studies have produced some concerns for nontarget insect effects (Losey et al. 1999), beneficial insects are generally not adversely affected by the Bt gene. Sap beetles may still be a problem in Bt corn, requiring insecticide treatment. Sap beetle trapping may be a useful and rapid alternative to conventional plant scouting for determining when insecticide application for sap beetle control in sweet corn is appropriate, and also be of use in dent (field) corn to determine when sap beetle control is appropriate for indirect control of mycotoxigenic fungi.

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